Friction **4**(1): 84–88 (2016) ISSN 2223-7690
DOI 10.1007/s40544-016-0101-2 CN 10-1237/TH

SHORT COMMUNICATION

On the risks associated with wear quantification using profilometers equipped with skid tracers

M. BELLANTONIO*

TRIBOtechnic, 4 Rue Valiton, Clichy 92110, France

Received: 22 October 2015 / Accepted: 14 December 2015

© The author(s) 2016. This article is published with open access at Springerlink.com

Abstract: In this study a wear track was generated on aluminium by rubbing it against a hard steel ball. The generated wear track has a typical depth of 50 μm and exhibits marked ridges on its borders. The cross section profiles were measured using two different stylus profilometers equipped either with skidless or skid probes and compared to a skidless reference instrument. It was found that the use of a skid probe can introduce significant distortion of the measured wear track profiles and thus errors in wear quantification. The reason for that is attributed to the presence of the ridges that, by elevating the skid, alter artificially the reference height used for profile measurement.

Keywords: profilometer; wear track volume; skidless profilometer; wear measurement; skidless tracer; skid tracer

1 Introduction

Measurement of the wear track volume using profilometers is a widely used technique for quantifying wear. This method is of high sensitivity and of rather simple use. Several types of instruments, such as white light interferometers, scanning laser or triangulation optical sensors and stylus profilometers are commonly used in tribology practice. Stylus profilometers offer a number of advantages compared to non-contact optical instruments. In these instruments, a small stylus scanned across the sample senses the surface. The surface profile is determined by continuously recording the vertical movement of the stylus with respect to a reference height. Stylus profilometers are immune of artefacts derived from local variations in surface optical properties due to deep valleys, large slopes or multiphase materials that may affect optical sensors [1]. Further, stylus profilometers can be commercially obtained as compact, cost effective instruments. Such instruments are particularly suitable for the determination of the wear track volumes generated during laboratory tribological tests. For this, typically cross section profiles are measured perpendicularly to the sliding direction. The cross section area can be determined by integrating the void area below the original profile height (the surface level before rubbing) over the width of the wear track [2]. The wear volume can be calculated by multiplying the cross section area by the length of the wear track [2]. Among the small stylus instruments, the so called slid tracer has been recently proposed as particularly cost effective wear measurement instruments. While classical (skidless) tracer measures the height of the stylus tip with respect to an instrument internal reference, skidded sensor uses as reference a skid (of much larger dimensions than the stylus) that contacts the surface and moves aligned to the stylus (Fig. 1). While the skidless probes sense both waviness (long range profile features) and roughness (short range profile features), measuring using the skid as reference levels out the waviness of the sample [3]. In the case of wear track measurement, the suppression of the sample waviness could constitute an advantage provided that the unworn surface is flat and smooth. This is in theory the case as laboratory samples are usually fine polished prior to wear tests. However, wear often leads to the formation of ridges

* Corresponding author: M. BELLANTONIO.
E-mail: info@tribotechnic.com

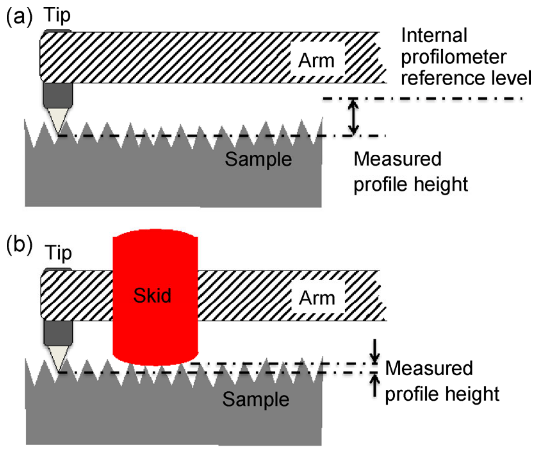

Fig. 1 Schematic view of a skidless skid (a) and a skid (b) profilometer.

on the borders of the sliding track. Since the skid senses the ridges, the reference height, corresponding in principle to the surface level prior to wear, becomes distorted. This may potentially introduce errors in wear quantification. On the contrary, skidless profilometers measure the entire profile heights including the ridges.

Thus, this study was initiated with the aim to verify to which extent skid tracer profilometers may introduce artefacts in wear quantification. For this an ad-hoc generated wear track was characterised using two commercial profilometers equipped with either a skidless tracer or a skid tracer. For comparison, reference measurements were taken with another commercial skidless stylus instruments. Obtained wear track profiles and wear data are compared and discrepancies are discussed.

2 Materials and methods

Tribological test: a wear scar was produced on a flat steel sample by rubbing against an alumina ball animated by reciprocating sliding. The tribometer used was a Tribotechnic Tribotester Model 200 N. The contact configuration involved a static aluminium plate against which a bearing steel ball (DIN 100Cr6, diameter 12.7 mm, roughness AFMBMA G10) was sliding in reciprocating alternate motion (sinusoidal motion with frequency 10 Hz, amplitude 4 mm). The applied normal load was 150 N and test duration was 900 s corresponding to a sliding distance of 72 m. The contact as lubricated with a grade 5W-30 oil and maintained at a temperature of 130 °C.

Height profiles were measured on the wear track perpendicularly to the sliding direction at distances of ½ of the scar length starting from one end of the scar (Fig. 2). The positioning of the stylus in the centre of the wear scar occurred manually and was thus affected by some uncertainty estimated to be less than 0.2 mm. In order to check for the influence of this uncertainty on the final outcome, the measurement was repeated using the same instrument (Profilometer 1) by repositioning at each time the stylus. For comparison, the same measurements were repeated but without repositioning the stylus on the sample.

The used instruments and the corresponding parameters are listed in Table 1. The skid profilometer was run at two distinct profile lengths to evaluate the effect of distance on waviness suppression by the skid.

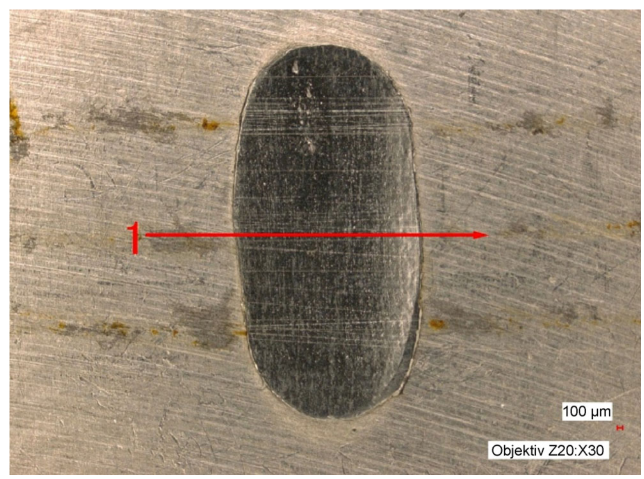

Fig. 2 Low magnification optical microscope image of the wear track. Height profiles were measured along the red arrow marked 1.

Table 1 The used instruments and the corresponding parameters.

Instrument	Skid	Tip radius	Profile length	Speed
Profilometer 1 Brand A	No	5 µm	4.8 mm	0.5 mm/s
Profilometer 2 Brand B	Yes	5 µm	16 mm	1 mm/s
Profilometer 3 Brand B	No	5 µm	10 mm	1 mm/s
Profilometer 4 Brand C	No	5 µm	15 mm	0.5 mm/s
Profilometer 5 Brand C	Yes	5 µm	6 mm	0.5 mm/s

3 Results and discussion

3.1 Cross section profiles

Figure 3 shows typical profiles as measured using different instruments. Pronounced, ridges can be observed in all profiles. The two skidless profilometers (Figs. 3(a) and 3(c)) yield very similar, symmetric profiles typical for the indentation of a ball into a softer metal. The presence of skid introduces several evident distortions of the profile: corrugation of the wear track as well as of the surface surrounding it, and loss of the track symmetry.

The distortions are due to the relative difference in height between the stylus and the preceding skid that follow the same profile but at shifted positions. For example the initial descent (from left to right) of the profile (d) can be attributed to the climbing of the skid on the left ridge generating an apparent descent of the surface. The changes of reference height (the skid) in the course of a measurement clearly yield a distorted profile that does not represent the real surface profile and thus can hardly be used for wear quantification as shown in the next section.

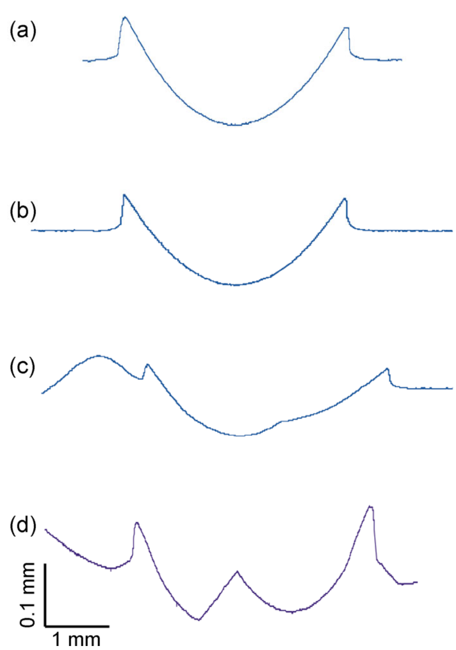

Fig. 3 Profiles of the wear track measured using different instrument: (a) skidless profilometer 1, (b) skidless profilometer 3, (c) profilometer 2 with skid, and (d) profilometer 5 with skid.

3.2 Quantitative aspects

For the appraisal of wear it is necessary to quantify the extent of the wear track as well of the ridges. The difference of both yields the amount of removed material, i.e., the amount of wear. The quantification was carried out on the measured profiles by first levelling the profile to compensate for possible misalignment between the sample surface and the translation direction of the probe. Afterwards, the points of the horizontal axis delimiting ridges and track were manually selected and the corresponding area surfaces were calculated by integrating the profile height over the length interval delimited by the selected points. Figure 4 shows representative examples of quantification for the profilometer 2 and 3 (same brand) with or without skid. Discrepancies exist between the dimensions of the wear track both in width and depth. The left and right ridges are symmetric only in the case of the skidless probe (Fig. 4(a)). The skid probe (Fig. 4(b)) yields a distorted and enlarged left ridge compared to the right one.

The wear scar cross section area (displaced material, red surface in Fig. 4) measured using the different instruments are compared in Fig. 5. This area is proportional to wear. Figure 5 shows that the quantification of cross section area using the same stylus profilometer is a robust method yielding reproducible values. The exact positioning of the sample under the profilometer seems not to be the most crucial factor affecting results scattering: indeed profiles (c) and (d) in Fig. 5 were measured as the same location but nevertheless exhibit similar differences cross section area as profiles (a) to (c) measured when repositioning the sample at each time. Different skidless profilometers yield slight variations in cross section area probably because of differences in tip geometry, sensitivity of the measurement electronics and calibration procedures. Not surprisingly considering the previously described distortions of the profile introduced by the skid is the much larger discrepancies introduced by the use of a skid: in case of the brand C instrument the skid profilometer underestimates the cross section area (and thus wear) by 25% while the brand B skid instrument overestimates wear by more than 25%.

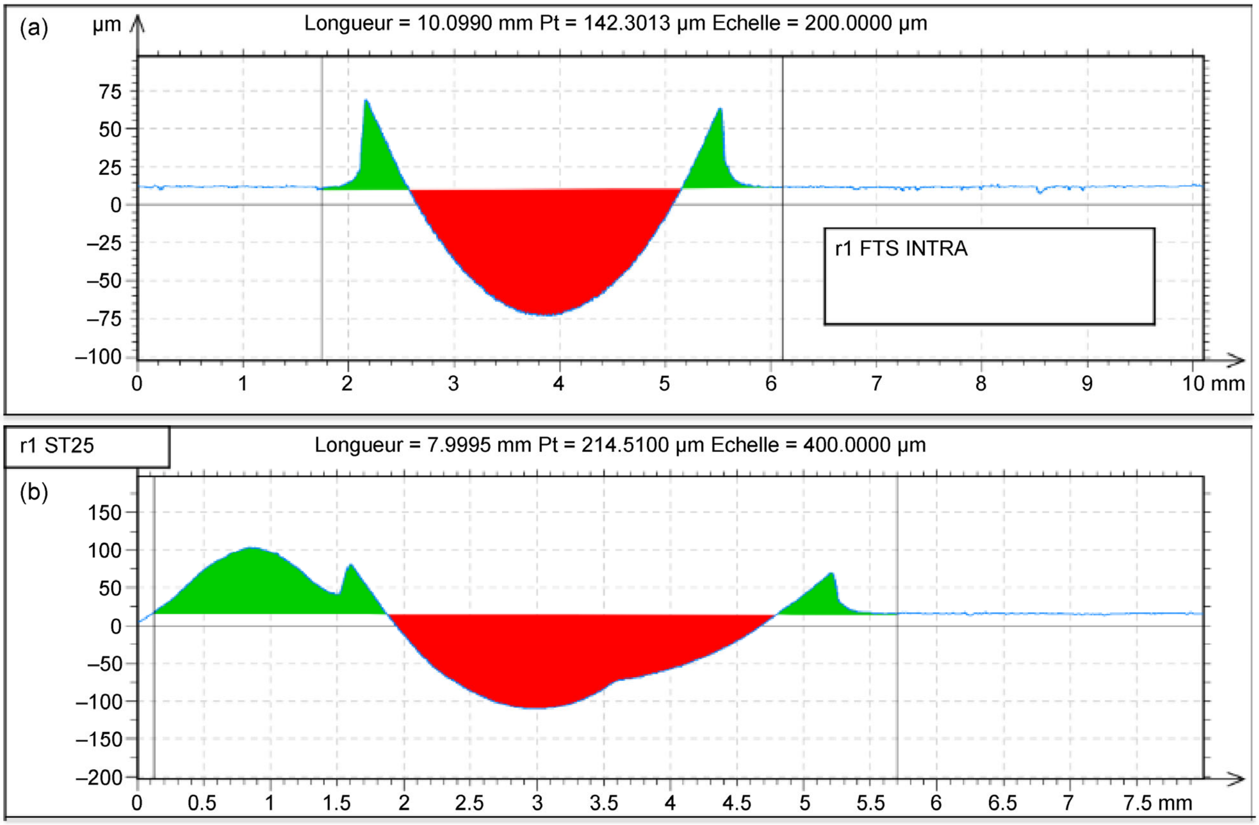

Fig. 4 Quantification of wear track (red) and ridges (green) cross section areas for profiles measured using profilometer 3 without a skid probe (a) and profilometer 2 with a skid probe (b).

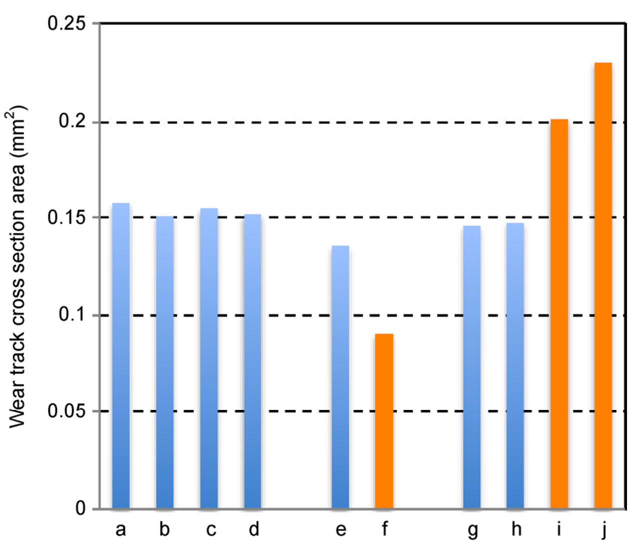

Fig. 5 Wear scar cross section (mm^2) for the different instruments: a, b, c: Brand A profilometer with renewed positioning in the centre of the track; d: repetition of c on the same location; e and f: Brand B; g, h, i, j: Brand C. Measurements without skids are plotted in blue, while the ones with skid (f, i, j) in orange.

4 Conclusions

These study shows that the use of a skid probe for measuring cross section profiles of worn surfaces characterised by ridges on either sides of the wear track can introduce significant distortions of the measured wear track profiles and thus errors in wear quantification. The reason for that is attributed to the presence of ridges that shift up the skid position and thus alter artificially the height reference of the skid probe.

Open Access: The articles published in this journal are distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References

[1] Vorburger T V, Rhee H-G, Renegar T B, Song J-F, Zheng A. Comparison of optical and stylus methods for measurement of surface texture. *Int J Adv Manuf Technol* **33**: 110–118 (2007)

[2] Ruff A W. Wear measurement, in friction, lubrication and wear technology. In *ASM Handbook Vol 18*. ASM International, 1992.

[3] David J. *Whitehouse Handbook of Surface and Nanometrology, Chapter 4*. CRC Press, 2002.

Marc BELLANTONIO. He has over 27 years of experience in the field of characterisation of coatings and bulk materials in tribology. He has also acquired skills in manufacturing tribometers, scratch testers and calotesters. He has lunched over 32 innovations in this field during last ten years.